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Designing Metacognitive and Motivation Tutor: A Pedagogical Agent to Facilitate Learning in Blended-Learning Environment in A Higher Education Context

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Abstract: In this paper, we present the initial results of research that is still ongoing in building metacognitive and motivation tutor, a pedagogical agent used to facilitate students in blended learning in a higher education context. The MeMo Tutor, which stands for "**Me**tacognitive and **Mo**tivation **Tutor**", is a pedagogical agent in the form of a conversational agent that integrated into the Moodle Learning Management System. The metacognitive and motivation tutor aims to provide feedback to students using an integration of metacognitive scaffolding and motivation scaffolding. The main objective of the pedagogical agent is to maintain and enhance student engagement and motivation in blended-learning environment. This paper presents the first results in ongoing research efforts. In this work, we attempt to design the components of the proposed pedagogical agent, consisting of a learning environment, character design, and system architecture.

Keywords: Pedagogical agent, blended-learning, higher education, metacognitive scaffolding, motivation scaffolding, learning environment, character design, architecture design

1. Introduction

Blended-learning is learning that commits instructors and students working together through a mixed approach, technology mediated and face-to-face, which is supported pedagogically through assignments, activities, and assessments that are tailored to the approach given (McGee & Reis, 2012). Engagement and motivation in the blended-learning process are important issues in the e-learning research field. Since engagement and motivation are potential to promote increased learning outcomes (Johnson & Lester, 2018). Numerous studies have been done by researchers and educators to promote and maintain student engagement and motivation in online learning. One of them is a pedagogical agent. Pedagogical agents are virtual characters in an online learning environment that function as learning tools by providing assistance, guidance, procedures or examples to support the learning process (Martha & Santoso, 2019). Pedagogical agent research continues to develop along with technological developments. The use of Natural Language Processing (NLP) technology in an intelligent agent environment has proven its success in the past. The input boxes on NLP forces students to express ideas explicitly and identify difficult fields (Carlson et al., 2012).

Scaffolding is a learning strategy that is considered most appropriate with the perspective of social constructivism (Olney & Cade, 2013). Pedagogical agents using scaffolding learning strategies have the potential to improve learning outcomes. At present, the use of scaffolding approach in pedagogical agent research has been carried out, but only focuses on metacognitive scaffolding. Based on the perspective of self-regulated learning, the success of online learning is influenced by two contributing components, namely metacognition and motivation (Eflkides, 2011). Motivation influences the level of student achievement, the level of engagement, and the quality of work (Hartnett, 2016). However, the design of pedagogical agents using a motivation approach is still very limited (Martha & Santoso, 2018). Therefore, the motivation scaffolding approach that integrates with the metacognitive scaffolding approach needs to be included in developing a pedagogical agent.

In this paper, we developed a pedagogical agent using a conversation interface, which was integrated with Moodle's Learning Management System. The character of the pedagogical agent is static. The pedagogical agent that is built has the purpose of maintaining and increasing student learning engagement and motivation, through stimulation from an integration of metacognitive and motivation scaffolding during the individual and collaborative learning process.

We recognize that the development of agents that are capable of supporting individual and collaborative learning through group settings is complex. In addition, the integration of metacognitive and motivation scaffolding also has a very complex construction in each part. Therefore, we limit the agent's design goals to one blended learning topic. The learning scenario of the topic will be explained in part four of this paper.

This paper begins with a brief summary of related works of pedagogical agent research, followed by illustrating the design of the learning environment to apply the developed pedagogical agent. Then we describe the overview of our proposed system. In the end, we provide conclusions and discuss our future work from the system being built.

2. Related Works

In the last ten years, the number of publications of scientific articles on pedagogical agents has continued to increase and further improve the features of existing pedagogical agents (Martha & Santoso, 2019). Some pedagogical agent studies, both those using metacognitive and motivation scaffolding methods, are presented in this section.

MIMIC is a pedagogical agent with three roles, namely motivator, expert, and mentor (Baylor & Kim, 2005). MIMIC works by using metacognitive scaffolding strategies. These three agents are able to simulate instructional roles effectively in accordance with student perceptions.

Betty's Brain is a pedagogical agent in the form of teachable agents (Biswas et al., 2009; Leelawong & Biswas, 2008; Roscoe et al., 2013). Betty's Brain acts as an agent taught by students. With the metacognitive scaffolding strategies, Betty's Brain is able to improve student self-regulated learning. Students with metacognitive skills are able to monitor the content and quality of their learning outcomes.

The Wayang Outpost uses motivation scaffolding strategies in the context of mathematics tutoring (Arroyo et al., 2011). Wayang Outpost focuses on gender issues in solving math problems. Wayang Outpost as a pedagogical agent is able to improve the affective outcomes of students in general and especially for female students, who feel more anxious when working on mathematical problems.

MetaTutor is a pedagogical agent acting as scaffolders using the metacognitive scaffolding strategies (Duffy & Azevedo, 2015; Harley et al., 2018; Taub et al., 2014; Trevors, Duffy, & Azevedo, 2014). In their research, the MetaTutor used prior knowledge to influence learning activities and subsequent learning outcomes.

The four pedagogical agents mentioned above use the learning context in the STEM (Science, Technology, Engineering, and Mathematics) field. This is in accordance with the results of the meta-analysis conducted by Schroeder et al. (2013), that the benefits of pedagogical agents appear to be slightly greater for the context of STEM learning than for the humanities. Several reasons were raised regarding the learning context (Cook, 2017). Firstly, the ability of pedagogical agents to signal possible and most critical information when studying abstract content or processes that are more general in the STEM context. Secondly, researchers argue that, if students have a perception that STEM content is more challenging rather than content in the humanities, the effects of increased engagement from agents can help them survive and work harder, leading to better learning outcomes.

This research will implement pedagogical agents in the context of STEM learning, specially linear algebra in the Faculty of Computer Science, Universitas Indonesia. The linear algebra course was chosen because this course has been offered in blended-learning for more than 10 years and the instructor has a long teaching experience. With the integration of metacognitive and motivation scaffolding in pedagogical agents, pedagogical agents are expected to be able to act as scaffolders that can increase engagement and motivation in blended-learning in higher education.

3. Methodology

This study is a part of a larger and ongoing research on pedagogical agent (Martha & Santoso, 2018; Martha & Santoso, 2019). The research in this study aims to create a pedagogical agent model. This type of research is a compensation type. In the type of compensation, qualitative analysis can compensate for the small sample size in quantitative studies (Venkatesh et al., 2013), therefore the quantitative methods should to be done first, followed by qualitative ones. Thus, the mixed-methods sequential explanatory approach (Cresswell, 2014) is the methodology applied in this study.

The stages of the mixed-methods sequential explanatory approach are as follows.

1) This study utilize a purposive sampling technique to select participants in the class at a state university in Indonesia, based on the homogeneity of scores in the level of e-learning readiness. The selected class is a class with students who have the same level of e-learning readiness. The instrument used to measure the level of e-learning readiness is the E-learning Competencies which was developed by Parkes and Reading (2013) which was adapted by Junus et al. (2017).
2) In the quantitative phase, quasi-experimental non-equivalent methods (Cresswell, 2014) are used. This method has several stages, as follows.
    a. Pre-test; the experimental group and the control group will be given a pre-test using the Metacognition Questionnaire (Garrison & Akyol, 2015). This questionnaire was chosen because the items reflect metacognitive monitoring and managing skills when students are engaged in individual (self-regulated learning) and group settings (co-regulated learning) (Garrison & Akyol, 2015). The questionaires has been translated and adapted by Junus et al. (2019). According to Garrison and Akyol (2013) in Junus et al. (2019), the metacognition construct was built to understand the role of students in the learning process, both as individuals and as group members. In Junus et al. (2019), the metacognition questionnaire can measure the metacognition of the experimental class using cognitive approaches in the asynchronous discussion process with significant results.
    b. Experiment; the experimental group will learn with a pedagogical agent (the MeMo Tutor) and control groups will learn without pedagogical agents.
    c. Post-test; the experimental group and the control group will be given a post-test using the same instrument in the pre-test.
3) In the qualitative phase, there will be an in-depth survey of the experimental group regarding user experience (Santoso et al., 2016) when studying with a pedagogical agent (the MeMo Tutor).
4) The next stage is analyzing and comparing the results of measurements from the experimental group and the control group.

However, the stages of the method above are still in the form of plans and have not been implemented. Overall the research schedule is illustrated in Figure 1.

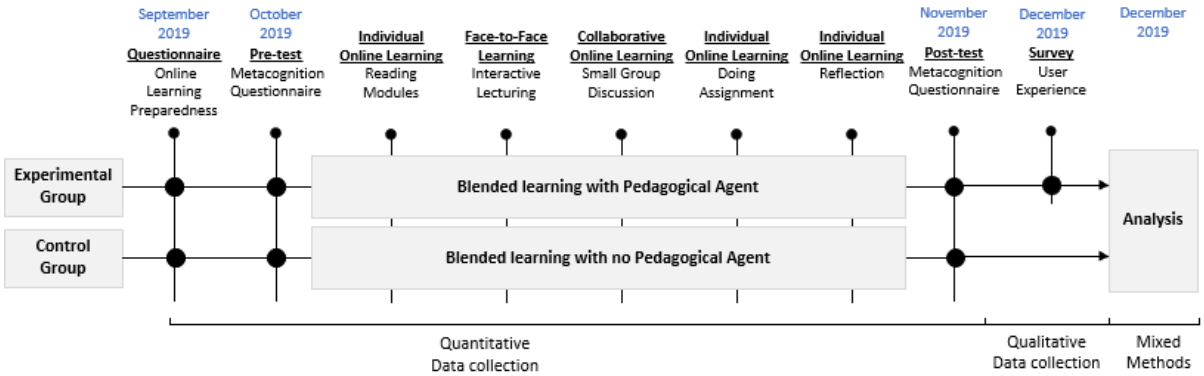

Figure 1. Research Plan.

Based on the research plan above, implementation will be carried out on the topic of linear algebra in blended-learning. In the experimental group, blended-learning activities (individual online learning, collaborative online learning and face-to-face learning) will be carried out with a pedagogical

agent. While in the control group, blended learning activities will be carried out with no pedagogical agents.

4. Proposed Pedagogical Agent

The design of the proposed pedagogical agent is discussed in six subsections, i.e. learning environment, character design, stages of work, overview of the system, system features, and learning scenario.

4.1 Learning Environment

The learning environment from the perspective of a teacher (Bates, 2016) is used to describe the learning environment in which the pedagogical agent implemented. The learning environment in this study consists of six components, i.e., learner characteristics, content, skills, learner support, learning resources, and learning assessment. The complete learning environment is illustrated in Figure 2.

The learning environment described in this paper is a learning environment that is commonly used in pedagogical agent research. To compare our study and previous research, we limit the citation of the learning environment to pedagogical agent research that focuses on the use of metacognitive and motivation scaffolding. The development carried out in this study is illustrated by a blue dashed line.

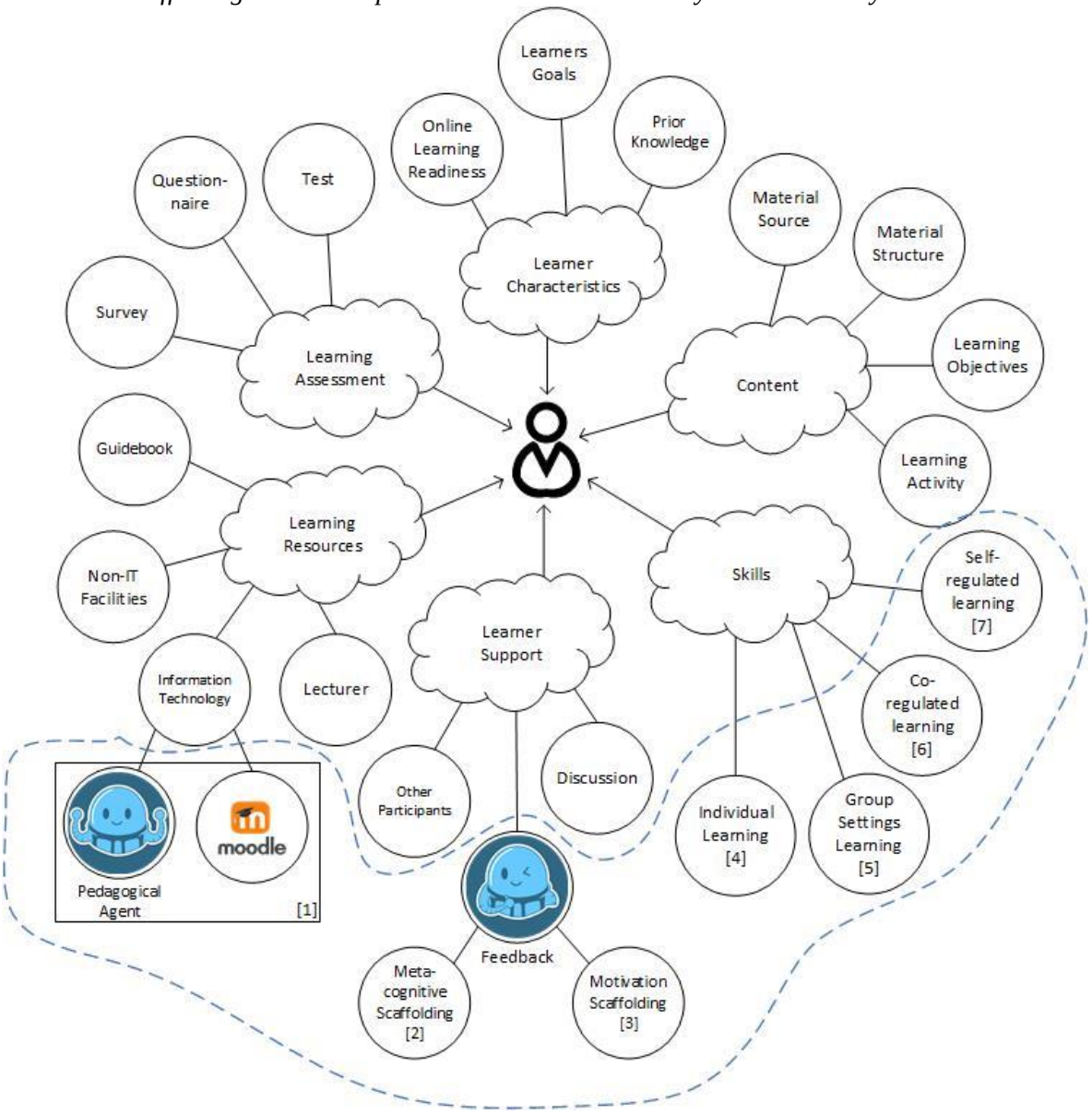

Figure 2. Learning Environment.

Previous studies in the learning environment according to the numbers in the Figure 2, as follows.

[1] The use of Moodle as a tool for pedagogical agents in interacting with students has been done considerable. However, research that focuses on the use of metacognitive and motivation scaffolding is mostly done using standalone applications. The utilize of the open source Moodle platform makes it easy for teachers to make updates to course content, so students can directly learn material content with the latest version (Yilmaz et al., 2017 and Yilmaz & Yilmaz, 2019).

[2] The utilizes of metacognitive strategies in pedagogical agents is often done. This is rational with the statement of cognitive science researchers, that metacognition has an important role in the development of effectiveness, both in class and outside the classroom (Baylor & Kim, 2005; Biswas et al., 2009; Duffy & Azevedo, 2015; Harley et al., 2018; Leelawong & Biswas, 2008; Roscoe et al., 2013; Taub et al., 2014; Trevors et al., 2014; Yilmaz et al., 2017; and Yilmaz & Yilmaz, 2019).

[3] The presence of pedagogical agents with motivational scaffolding strategies can motivate students in the learning process (Arroyo et al., 2011 and van der Meij et al., 2015).

[4] The implementation of pedagogical agents in individual learning can identify the performance of each student, therefore student achievement can be analyzed more deeply (Arroyo et al., 2011; Baylor & Kim, 2005; Biswas et al., 2009; Duffy & Azevedo, 2015; Leelawong & Biswas, 2008; Roscoe et al., 2013; Taub et al., 2014; Trevors et al., 2014; van der Meij et al., 2015, and Yilmaz et al., 2017).

[5] The implementation of pedagogical agents in collaborative learning can describe student engagement in learning (Harley et al., 2018 and Yilmaz & Yilmaz, 2019).

[6] Co-regulated learning can diagnose how students are able to support one another in learning (Harley et al., 2018).

[7] Self-regulated learning can provide a comprehensive picture of how students are able to set and implement learning strategies (Biswas et al., 2009; Duffy & Azevedo, 2015; Leelawong & Biswas, 2008; Roscoe et al., 2013; Taub et al., 2014; Trevors et al., 2014; and Yilmaz et al., 2017).

In this study, we integrate the pedagogical agent with Moodle to facilitate learning in higher education. The Pedagogical agent provide feedback to students by using the integration of metacognitive and motivation scaffolding. Pedagogical agent implementation will be carried out in individual learning and group settings. The use of pedagogical agent during the blended-learning process is expected to enhance students' self-regulated learning and co-regulated learning.

4.2 Character Design

The MeMo Tutor is an acronym for Metacognitive and Motivation Tutor. The first idea when modeling the character of the MeMo Tutor is to create static cartoon characters. The cartoon character taken is a form of a robot (non-humanoid), as shown in Figure 3. The non-humanoid characters was chosen to avoid bias from gender use which might affect interaction with students.

Figure 3. The MeMo Tutor.

The MeMo Tutor is intended as a pedagogical agent that helps students to study online in higher education. Therefore, the character of the MeMo Tutor is described by a simple figure with an uncomplicated face so that learning activities become more enjoyable. The smile on the MeMo Tutor's face indicates that this character is friendly and warm. While the two hands raised up to characterize the

spirit. Overall, the default character of the MeMo Tutor means a friendly and warm character that gives spirit in learning activities.

Some gestures are added to the characters used when giving explanations or feedback. The gesture consists of talking/explaining, thinking, learning, good work, sad, and surprise. The six gestures are illustrated in Table 1.

Table 1

The MeMo Tutor Gesture

Gesture	Image	Description	Example
Talking/ explaining		Shown in: • Planning (metacognitive scaffolding)	Guide students in preparing for learning or assignments, such as identifying assignments, distribution of tasks in groups, etc.
		• Establish task value (motivation scaffolding)	Encourage students to choose to do their most preferred assignments first.
		• Evaluation (metacognitive scaffolding)	Helping students correct mistakes.
Thinking		Shown in: • Monitoring (metacognitive scaffolding)	Provide support when students study the material, comment on the activities of each group member in the discussion, etc.
Learning		Same with talking/explaining gesture.	
Good work		Shown in: • Promoting mastery goals (motivation scaffolding)	Give feedback, give appreciation, etc.
		• Promote emotional regulation (motivation scaffolding)	Provide emotional support when working on a difficult task, helping students know the causes of failure and how to overcome them.
Sad		Shown in: • Evaluation (metacognitive scaffolding)	Point out failure when completing a task.
Surprise		Shown in: • Reflection (metacognitive scaffolding)	Provide performance feedback, provide suggestions or criticisms, etc.
		• Promoting autonomy (motivation scaffolding)	Provide information on student learning goals.

4.3 Stages of Work

The pedagogical agent built using an integration of metacognitive and motivation scaffolding in providing feedback. The pedagogical agent model in this study has several stages of work. Stage 1: Students begin interactions with the MeMo Tutor through Moodle LMS. Students need to choose topic to be studied. Stage 2: The MeMo Tutor identifies student profiles and presents learning statistics about selected topics to students. Stage 3: The MeMo Tutor provides material reviews on selected topics (containing questions and answers between agents and students to improve student understanding).

Stage 4: Next the MeMo Tutor provides quizzes/assignments (containing questions that need to answer by students). Stage 5: The MeMo Tutor provides the results of the evaluation of the learning performance that has been carried out by students.

4.4 System Overview

The Pedagogical agent in this study has a role as scaffolding who will provide questions and answers, evaluations, and feedback. The pedagogical agent will be integrated into the conversation interface in the Learning Management System Moodle version 3.3+. The language used is Bahasa Indonesia, according to the language used by students in this research experiment. This is important, to ensure students to feel comfortable when interacting with pedagogical agents during the learning process.

We use the Dialogflow API (Gelfenbeyn, 2010) as an NLP API tool in building conversation interfaces. This is because building NLP components from the start is very complex and will take time. By using Dialogflow API, we can focus more on the main objectives of the development of the pedagogical agent than the NLP design.

Overview of the system architecture shown in Figure. 4 shows the process of how the pedagogical agent works through web platforms. The proposed system allows students to interact with the pedagogical agent on material topics to be studied in a session. This system works by utilizing Node.js so that the Moodle database and the MeMo Tutor database can communicate. In addition, Node.js is also used to make feedback queries with a combination of metacognitive scaffolding strategies and motivation scaffolding (this integration of the scaffolding is not discussed in this paper). The use of Node.js was also conducted to monitor student activities, as well as identify student profiles.

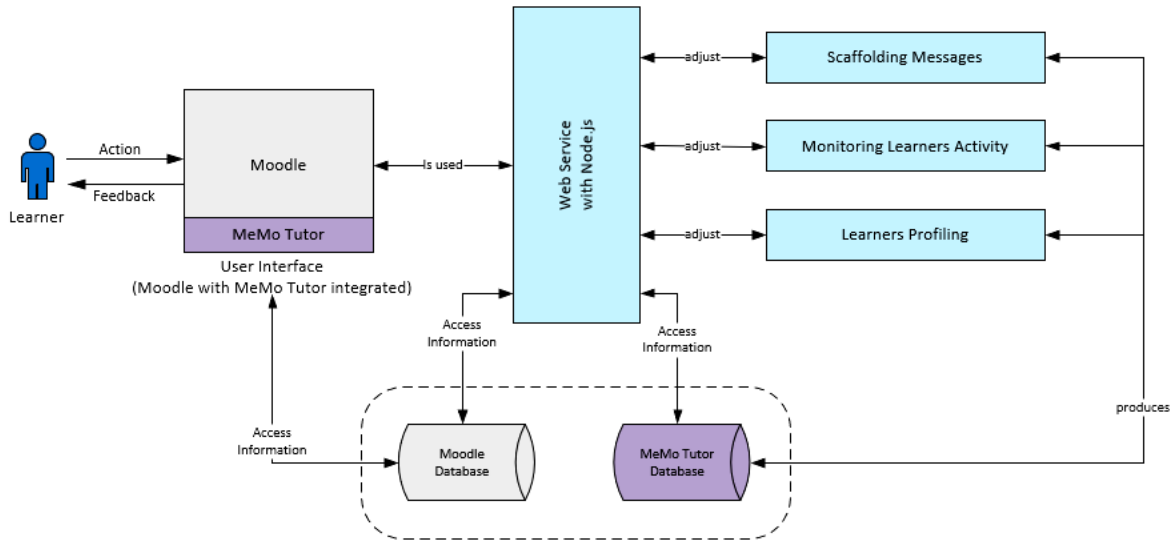

Figure 4. An Overview of Proposed Architecture Systems.

4.5 System Features

The MeMo Tutor is a pedagogical agent that functions as a learning tool used on the Moodle platform. The MeMo Tutor facilitates students to study online in individual and in group settings. This pedagogical agent consists of two main modes: Individual Mode and Group Setting Mode.

Previous research on pedagogical agents using metacognitive scaffolding and motivation scaffolding, was carried out only on individual or collaborative learning. From the results of the previous studies, pedagogical agents can significantly improve students' self-efficacy (Baylor & Kim, 2005; van der Meij et al., 2015), showing better self-regulated behavior (Biswas et al., 2009; Duffy & Azevedo, 2015; Leelawong & Biswas, 2008; Roscoe et al., 2013; Taub et al., 2014; Trevors et al., 2014; Yilmaz et al., 2017), increasing affective outcomes especially for female students who are more often frustrated and lacking confidence when solving math problems (Arroyo et al., 2011), and increasing engagement in groups (Harley et al., 2018; Yilmaz & Yilmaz, 2019).

In contrast to previous studies, in this study pedagogical agents will be used in individual learning and collaborative learning with group settings. This is in accordance with the objectives of this study, i.e. improving self-regulated learning (individual mode) and co-regulated learning (group setting mode) of students.

In individual mode, the proposed pedagogical agent helps students when reading modules, doing exercises or assignments, and provides reflections on student performance. In group setting mode, the proposed pedagogical agent acts as an adviser in the discussion of the topic given. The discussion contains an understanding of the material and assignments that must be completed by a group of 3-4 students. The system will store student log data, student action/answer data, and discussion data. These data are expected to provide information about the level of student engangement in the learning process.

Based on these system features, we proposed four hypotheses that fit the research objectives, as follows:

Hypothesis 1: an experimental group that conducts learning with a pedagogical agent, understands the material better than the control group.

Hypothesis 2: the experimental group that did learning with pedagogical agents, had a higher score on the test compared to the control group.

Hypothesis 3: the experimental group that did learning with pedagogical agents, had better discussion skills compared to the control group.

Hypothesis 4: Overall, based on log data and discussion data, the experimental group provided better engagement than the control group.

4.6 Learning Scenario

Pedagogical agents will be implemented on a topic in a linear algebra course. The learning scenario of the topic is illustrated in Table 2 below.

Table 2

Learning Scenario

Course	Linier Algebra
Topic	Linear Dependency, Basis, and Dimensions
Goal	1. If given vector space, students can construct subspaces, and determine whether a subset with certain requirements is subspace. 2. If given set vectors in a vector space, students are able to determine the linear dependency relationship between vectors. 3. If given a finite vector space and set of vectors, students are able to construct vector bases and determine their dimensions.
Roles	1. Support staff: Lecturer, Assistant. 2. Learner
Learning resources	Presentations files, lecture notes, textbook.
Type of learning setting	Lecture, exercise, and self-learning.
Teaching-learning environment	Blended-learning: Face-to-face, individual online learning, and collaborative online learning.
Technology-based platform	LMS Moodle, pedagogical agent.
Learning activities	Reading modules, interactive lecturing, small group discussion, doing assignment, and reflection.
Individual work	Reading modules, doing assignment, and reflection.
Collaboration	Small group discussion.
Assessment	Test and Discussion.

5. Conclusion and Future Works

In this paper, we propose a design of a pedagogical agent, called the MeMo Tutor, utilized in a blended-learning environment for a higher education context. The MeMo Tutor facilitate students in learning a subject by applying an integration of metacognitive and motivation scaffolding. The proposed pedagogical agent uses conversation interfaces as a communitcation tool. The language chosen for communication is Bahasa Indonesia, the national language of Indonesia.

The MeMo Tutor scaffolds students in designed phases tailored to the abilities of students. This pedagogical agent help students to expand their knowledge and apply it in the new context to promote student engagement and motivate them to learn online.

Prior the completion of the development of the agent, the effectiveness of the agent in promoting online learning will be conducted. The domain selected for the quasi experiment of a Linear Algebra course, since this course has been offered in a blended-learning approach for more than ten years and the instructors have long teaching experience. The course consists of eight topics. The study will evaluate the implementation of the agent on each topic and evaluate the results.

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